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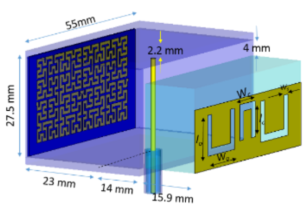
Vedaprabhu Basavarajappa and Vincent Fusco

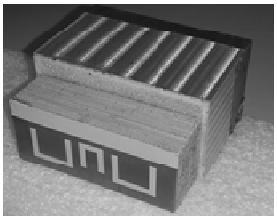
A dual/tri-band evanescent waveguide antenna element is presented. The antenna operates in the 740-790 MHz, 1.9-2.2 GHz, and 2.5-2.7 GHz frequency bands. It measures 55mm x 27.5mm x 53mm and occupies a small volume making it attractive for miniaturized applications.

Introduction: Crowded frequency spectrum necessitate the deployment of multiband antennas in order to minimize co-band interference. An evanescent waveguide radiator with multiband operation is presented which can fulfil this function. In [1] multiband antenna operation was obtained using a Sierpinski fractal, while [2] proposed a planar monopole antenna with dual band notch characteristics using shaped slots included in the radiator. In [3] a multiband multiple ring monopole antenna design was proposed that used planar resonators to excite multiple resonances.

Classical waveguide antennas operating at L and S-band and below are generally too large for applications where space is a premium. A propagating rectangular waveguide which used multiband split ring resonator loaded slabs along the waveguide sidewalls and along its centre enabled tri-band operation, [4]. Due to its construction from propagating waveguide the resulting structure occupied a large volume. On the other hand evanescent waveguide antenna, EWGA, [5], which work on the principle of matching the reactive aperture admittance of a cut-off waveguide to free space occupy reduced volume as compared to propagating waveguide antenna equivalents. To the author's knowledge no examples of multiband EWGA have been reported. The purpose of this paper is to redress this.

Antenna: The proposed antenna is based around an evanescent waveguide designed to operate in below cut-off mode, Figure 1. It operates with vertical linear polarization in the 1.9 -2.2 GHz and 2.5-2.7 GHz cellular bands and is excited at port 1, with port two exciting horizontal linear polarization at the 740-790MHz white space frequency band, [6].





a *b*

c

Fig. 1 *Multiband EWGA:*
a schematic
b photograph
c Fractal backplane

The EWGA was fabricated using an extruded aluminium casing, Fig. 1b, with cellular bands excited using a coaxial probe inserted into its base wall. On the open end of the antenna is added a 0.7mm foam layer onto which is positioned a stack of 5 layers of 3.18mm Taconic RF 60 substrate material which are bonded together using Tacbond film. U slot resonators are printed onto the front face of the outermost dielectric stack substrate.

The evanescent aperture was selected as 55mm x 27.5mm (cut-off frequency of 2.7 GHz). The choice of the broad waveguide dimension is selected to be approximately $\lambda_0/2$ at the highest operating frequency of the antenna. The vertical dimension of the waveguide is chosen so that its aperture admittance looking into the waveguide can be matched to the waveguide characteristic impedance using an air-spaced dielectric transformer over the entire frequency band 1.9-2.7 GHz. Transmission resonances are introduced at 1.9 -2.2 GHz and 2.5-2.7 GHz in order to make the design dual-band. This was achieved by patterning a dual-band frequency selective surface unit cell comprised of U shaped slots on the top outer surface of the stack. The slot dimensions are given with reference to Fig.1a in Table 1.

Parameters	Description	Value (in mm)
l_o	Length of outer slot	11.4
w_o	Width of outer slot	14
l_c	Length of center slot	8
w_c	Width of center slot	8
w_s	Thickness of the slot	2

Table 1. Slot dimensions in mm

A 4mm air gap introduced at the top of the dielectric stack reduces the effective Q of the structure, to allow bandwidth compliance in the 1.9-2.2GHz and 2.5-2.7GHz bands. The slot configuration is symmetrical in order to facilitate radiation pattern symmetry. The center inverted U slot couples energy between the two outer U slots and the aperture matching process. The port 1 coaxial probe is introduced close to the aperture through the base wall of the structure and its length adjusted for simultaneous best return loss in each band.

Accommodation of the lower band 740-790 MHz requires an inherently electrically long antenna which should integrate into the already designed dual band antenna. To achieve this the solid metal short circuit back wall of the EWGA was replaced with a fractal dipole antenna which has dense enough metallization to approximate a solid conductor in the higher operating bands. A space-filling fractal resonator, [7], was designed to occupy this space, see Fig. 1c. The fractal antenna element was printed on one side of a grounded dielectric ε_r 3.55 and thickness 0.5mm. The fractal arm was meandered up to the 4th iteration of the Hilbert fractal curve and its aspect ratio modified to fit into the available rectangular space. The fractal arm was fed at its center by a coaxial probe positioned at right angles and at the center of the back face of the EWGA. The lengths of the fractal arms were set to resonate at 765 MHz.

Results: Figure 2 shows the measured and simulated return loss obtained without external additional port 1 matching applied, and simple LC matching at port 2.

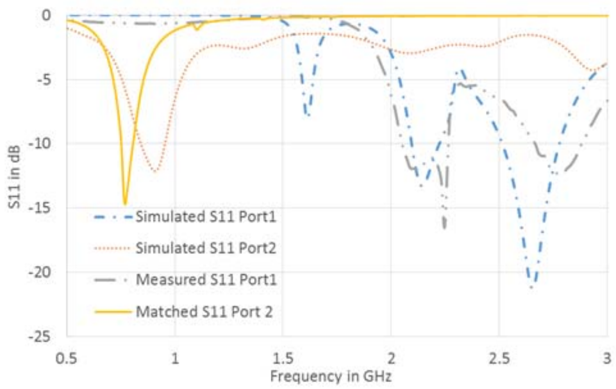


Fig. 2 *Return loss*

The principle radiation patterns of the antenna are presented in Fig. 3. For the cellular band mid-band frequency points 2.1 and 2.6 GHz, sidelobe levels were below -15 dB. EWGA gain measured using the comparison method were 5 dBi in the lower band at 2.1 GHz and 8dBi at 2.7GHz GHz. At 765 MHz S11 was less than -10 dB with a bandwidth of 50 MHz and gain 2.1 dBi.

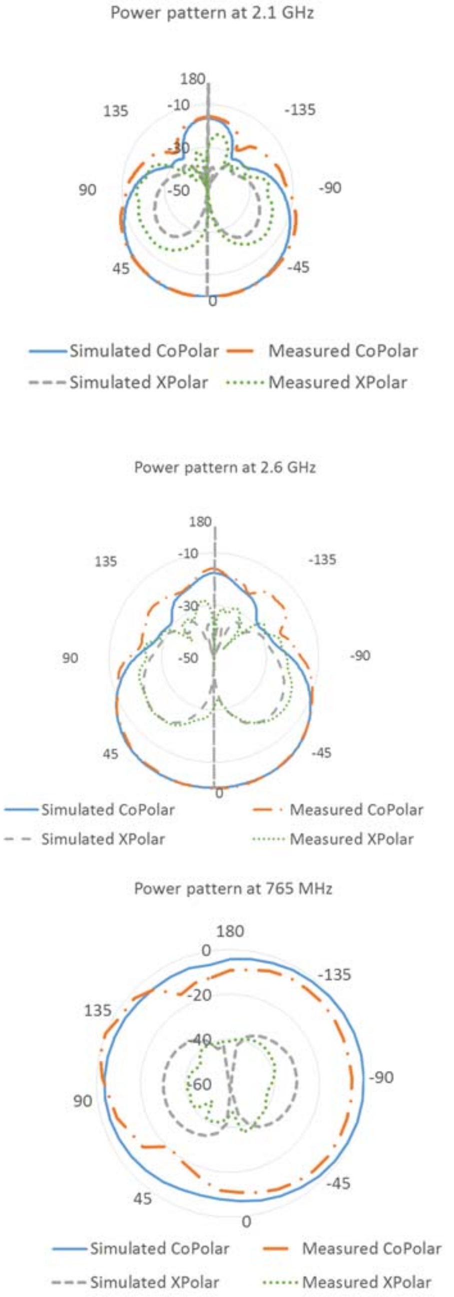


Fig. 3 *Comparison of simulated and measured radiation patterns*

Conclusion: A dual/tri-band evanescent waveguide antenna has been presented. The antenna operates in the 740-790 MHz white space, 1.9-2.2 GHz and 2.5-2.7 GHz cellular frequency bands. The EWGA reported could be a possibility for insertion into next generation pico-cell equipment that require increased service facility in the lower frequency bands as well as form factor miniaturization.

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